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LIST OF MEMBERS—JULY, 1880.

ERRATA.

Page 8, 9th line from bottom, for Bot. read Bvt.

Page 14, 10th line from bottom; for MENDELL, GEORGE A. read—
MENDELL, GEORGE H.

Page 21, 9th line from bottom, for Feb. 17, 1879, read—
Feb. 17, 1867.

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(Vol. IX.—January, 1880.)

INTER-OCEANIC CANAL PROJECTS *

DISCUSSIONS

By WALTON W. EVANS, FREDERICK M. KELLEY, CHARLES A. SWEET, JOHN C. CAMPBELL, CHARLES D. WARD, N. APPLETON, S. F. SHELBOURNE, MAX E. SCHMIDT, THOMAS J. LONG and EDWARD P. NORTH.

Discussion by WALTON W. EVANS.

I beg to offer a few remarks in discussion of Mr. Menocal's paper on the much-vexed project of the Inter-Oceanic Canal. I wish to give, first, my reasons for venturing an opinion:

1st. I have served for seven years as an engineer in the construction of canals.

2d. I have had an experience in the construction of public works of over forty-two years.

3d. I have crossed the Isthmus many times—partly by foot, by mule, by canal, and by rail.

4th. I have been detained on the Isthmus for weeks—by rains, revolutions, and want of transportation—before the railway was built.

*Inter-Oceanic Canal Projects. A. G. MENOCAL, No. CLXXXVIII., Vol. VIII., page 311 (November, 1879.)

5th. I have witnessed the heavens open their flood-gates, and seen the terrible washings the railway was subjected to.

6th. I have lived in earthquake countries for eleven years, and have witnessed the convulsions of Nature on the Isthmus as well as in Peru and Chile.

7th. I have, for over thirty years, made a study of this most interesting problem of cutting a canal for the largest ships through the narrow strip that divides North from South America.

8th. And I have read with care most of the public documents published in reference to it, and am clearly of the opinion that the "San Blas" route for a sea-level canal is far preferable to the Nicaragua route, with locks, or any other route ever reported on.

I beg to present some axioms in reference to this great problem:

1st. A canal thirty miles long is preferable to one a hundred and eighty-one and one-quarter miles long.

2d. A canal without locks is preferable to one with locks.

3d. A canal that has good harbors at its *termini* is preferable to one with no harbor at either end.

4th. A canal built in a healthy region is preferable to one in an unhealthy region.

5th. A canal that can be navigated in ten hours is better than one requiring one hundred hours.

6th. A canal that will call for very small repairs is preferable to one requiring immense repairs.

7th. A canal that has a small "water-shed," but a sure supply of water, is preferable to a canal having a great "water-shed."

8th. A canal that is not on a line of drainage is preferable to one on a line of drainage.

9th. A canal that can pass a ship of any length is preferable to one that limits the length to far below that of many existing ships.

10th. A canal that is virtually a straight line is preferable to one with many curves, some of them very objectionable.

I have read with care Mr. Menocal's clever paper, and beg to take issue with him on some points. He starts off with the assertion that the matter is narrowed down to two routes—the Panama and the Nicaragua. I should have been better satisfied if he had said the San Blas and the Nicaragua, for I look on the Panama route for a sea-level canal as simply ridiculous. I intimated the same,

but with less forcible words, to Count Ferdinand de Lesseps, in Paris. After many years of study of this matter, and after for a time believing in the Nicaragua route as the proper one, I came to the conclusion that the San-Blas route had many features in its favor that placed it far in advance of all others. I refer to the foregoing axioms for those features. I beg to say a word in defense of Count Lesseps. I have an impression that he is thoroughly honest, and find that is the opinion of all my friends in Paris who know him well. I think he was, in the conducting of the Congress influenced by men, who hoped to grow rich through the use of his name. He will soon see the error he has made when he reaches the Isthmus, and is made acquainted with the terrible destruction of the late floods. He said to me in Paris: "There is one point in this matter we must observe: wherever the canal is built *it must be a sea level canal.*" In this I fully agree with him; and I will add one more important engineering feature: it must not be built on any line of drainage, or across any line of drainage. What we require —what the world requires—is a perfectly reliable canal, that cannot by any accident run itself dry; that is perfectly secure against the accidents that can occur and do occur to all canals depending on dams and locks as working features, no matter how well and costly they may be built; if we cannot give the trade of the world such a canal we had better give it none.

I would not propose to run the San-Blas canal into the Rio Bayano, but turn that river off into the Bay of Panama by a cut made expressly for it; this could not be done for the Chagres River, except at an expense of many millions. It is proposed to build the Nicaragua Canal in the Valley of the San Juan, and in close contact with the river for many miles. I would suggest to the advocates of that route, and to the capitalists who I am told stand ready and eager to put their money in it, to first visit the Valley of the Lehigh, in Pennsylvania, and view the ruins of what was, within my recollection, a canal that received the praise and admiration of everybody; it was built by skilled engineers; the money furnished by the most careful and long-headed Quakers of Philadelphia; it had locks of thirty feet lift, the greatest ever put on a canal; the water-shed of the Lehigh is very insignificant; all the owners slept, no doubt, quietly in the possession of what they supposed to be a very safe investment; but a storm came—a flood was the result; this little lamb-like river became a great, fierce tiger, bent

on destruction; a weak point was found in the upper dam, the tiger poked his nose in it; a little leak was started, and away went the whole structure; with it went every dam and lock on the whole river, and hardly left a wreck behind; no one ever had the courage to rebuild that canal. There are many among us that recollect the destruction of the Croton River Dam; placed at the initial point of the Croton Aqueduct, it was built under the plans and direction of that Nestor in American engineering, John B. Jervis; he was an old and skilled canal engineer. Who have we at the present day who is his superior? That dam was built on rock, where the best of materials and skilled workmen were to be had in profusion; but it went—carrying havoc in its course—and destroyed every bridge, dam, mill, factory, and building it could reach down to the Hudson River. I well remember this river above the dam, and its lamb. like character in summer, for I built a railway on its banks, and have many times crossed it on stepping-stones without wetting my boots. The European news of the past two days tells us of floods in Hungary, and that many dams have been carried away on branches of the Danube. I for one would rather trust to a tunnel than a dam. I have had a good deal to do with dams, and I feel towards them as Robert Stephenson once told me he felt toward railways, that he was afraid of them.

There are other things that I would be afraid of in the construction of a canal with elevated reaches on the side of a valley where such rains occur as are frequent in the San-Juan region, I mean the melting and running of the embankments. Once on arriving at Panama on my way home I was told I could not cross the Isthmus, as there was a washout a few miles from Panama. I took a hand-car, went to see it, and found Col. Totten there making an embankment of sleepers. This same embankment had been washed out three times before, and every time it had been, when rebuilt, reinforced by a row of piles, close together, on the down-hill side. Col. Totten said to me, "You see this embankment could not go out down hill this time, so it has gone *up hill.*" It had actually squashed out on the up-hill side, and had run very much as molasses would run; a horse or man going into it would soon have gone out of sight. To know the Isthmus and its rains, and what rains can do in the way of making running mud out of embankments, it is necessary to go there and see it, for no one can imagine it from any pen sketch. I have an impression that all the arguments that

can be urged against the Panama route will hold good against the Nicaragua, while the Panama route, adapted to have locks, has the advantage over the Nicaragua in the matter of length and harbors at the termini.

Mr. Menocal's estimate of cost appears to be made as many other estimates of cost of public works have been before his time, by dealing in too small figures, and making omissions. His estimate for drains (I suppose this covers aqueducts over side rivers, culverts over streams, changes of channels, waste-wiers, sluices, &c., &c.) is magnificently deficient, and I see no items for protection walls, inside and outside, puddle walls, lining to prevent leaks, gravel facings, &c., &c. Also draw bridges over the canal, light-houses, machine-shops, and whole villages of buildings for residences, &c., store-houses, &c., &c. I suppose these are all in the twenty-five per cent. for contingencies. I have found in practice that after estimating every item I could think of, the twenty-five per cent. for contingencies came in as a most comfortable assistant at the end. Captain Young, who built the Utica Railway, used to say that the only safe way to make an estimate, was to take the largest quantities you could get from the profiles, carry them out with the largest prices you ever heard of, add twenty per cent., and then double the whole. When the first estimate of the Hudson River Railway was made, there were many arguments offered to show that it could be built for about "half of nothing;" the engineer gave the size and number of every arch and culvert required on the whole 145 miles, for each division. I, having a love of statistics, counted them, and found there were about sixteen or eighteen in all. Now, this same engineer had just before built the Croton Aqueduct over forty miles of the same route, and close to it, and had forgotten that he had built over three hundred culverts, arches, and bridges, on that forty miles. The protection walls for this railway, amounting to over 400,000 cubic yards, were estimated to cost fifty cents per cubic yard, and it was forgotten that the protection walls of the Croton Aqueduct (now nearly all, inside of forty years, replaced by better walls) cost $1.75 per cubic yard. I mention these things to show how errors creep into engineers' estimates, even among the most conscientious—their zeal, their desire, their anxiety to see their project go down the throats of somebody, overrides their judgment and stores away in oblivion for a time all their hard-earned experience, making true at this day the old Roman motto, "*Men try to believe what they wish to be true.*"

The Nicaragua route calls for the construction of artificial harbors at each *terminus*. This is a most unfortunate feature of this route. Such things have to be approached with fear and trembling, and a pocket full of money, and after they are built and handed over as something to be proud of, they, or their parts, very often go on excursions up and down the coast, through the alluring enticements of the wind and the sea. Some have their usefulness nipped in the bud by a failure to find funds for their completion, as was the case with the Dover Harbor, in England. I had occasion to examine those works in 1853, and then came to the conclusion that although "John Bull's" purse was long and large and full, that he had better leave that work alone, and since then he has left it severely alone. The one long wall which I saw in 1853, I was again on in June of this year, and found it had neither grown higher, longer, nor more complete, and its partner had never been attempted. In March of this year I walked, or rather clambered, out for a short distance on the concrete breakwater for the harbor of Port Said, at the northern *terminus* of the Suez Canal, found that it was far from finished, and unless finished would in a few years be knocked to pieces and rendered useless. In November of 1878 I had a chance to examine the concrete works of the harbor at Algiers, built by the French, evidently at great cost. The waters of the Mediterranean had quietly or unquietly, as the case may be, just knocked a considerable part of it into a "cocked hat," and the Algerines were, in their faith, no doubt, praying to "Allah" to knock the "cocked hat" into "pi."

Artificial harbors are contrivances to be avoided, if possible; they are apt to give engineers sleepless nights, to deplete plethoric pockets, and vanish when called on by the winds and the waves.

I have some experience in sleepless nights produced by things of this kind, for I built out into the Pacific Ocean the first pier ever built on the whole coast of South America, that a big ship could haul alongside of. The "Brave south-west winds" as Maury called them, were my friends for thirty days out of thirty-one, then "Æolus" sent "Boreas" down to make things lively with his "big guns," and at the same time make an engineer's heart sink into his boots. During construction I often saw the northers rolling in the waters, which went over my pier from 20 to 30 feet high, and bid fair at times to carry the whole structure, with its 80 000 tons of stone, on to the beach.

Mr. Menocal estimates the locks between gates to be 400 feet long;

a lock of this length will pass a vessel of only 360 feet. Thirty years ago vessels of 360 feet long were scarce articles; we have now lots of vessels of 450 feet, and vessels of over 500 feet are being built. Who can say what will be the length of vessels in another thirty years? The locks of the Erie Canal of 1825 could not pass boats of half the size that are now locked through.

The locks of the Delaware and Raritan Canal had not been in use thirty years before they had to be doubled in length. I came through the Suez Canal in March in a Peninsular and Oriental Royal Mail steamer from Hong Kong and Bombay, that was over 400 feet long; other steamers of that line are over 450 feet long. I saw a number of steamers in the canal, and judge that most, if not all of them, were over 400 feet long; it would be a sorry mistake to build a canal with locks that cost over $300,000 each, and find that they could not pass these giant craft, for they are the cream of the business a canal company would seek.

The Suez Canal is virtually a straight line. When I arrived at Lake Timsah we found a huge steamer stuck in the mud in the lake, and a crowd of Arabs unloading her; the canal ahead was blocked; I took a steam pilot-boat, went ahead to see the difficulty, and found that a passing steamer had run into and sunk one of their large dredging machines; this once clear, the next day our Leviathan attempted the passage to Port Said, but we had hardly run in the canal a mile before our vessel run her bows into the right bank, her stern slewed around and went into the left bank; there we stuck for two hours, and in two hours more our craft was laid along side for the night, that being her second day in the canal; this steamer entered the canal at 4 P. M., March 22d, and arrived at Port Said at 10 A. M. on the 24th, taking 42 hours to run just 100 miles in a sea-level canal, virtually one straight line. The very next mail steamer of the P. & O. line that came through after I did, ran into the bank, her stern swung into the opposite bank, and broke off two of the blades of her propeller. Accidents like this, of running into the banks, being apparently common on straight lines, it would be well to examine carefully into the manner of working these long steamers around the sharp curves of the proposed Nicaragua Canal.

We in America know that the English locomotives have a very unmannerly habit of jumping the track at sharp curves, which habit we in America have almost entirely eradicated from their vicious propensity by

rendering them subservient to the ameliorating influences of a "Bogie," a mechanical persuader which accomplishes the object in a most satisfactory manner; if this admirable invention could be applied to a ship, we might overcome the difficulty; as yet I see no manner of making the application, but the Yankee brain is prolific, and some genius may work out the conditions of this important problem. Old canal men and sailors accustomed to handling these huge vessels will look with a smile on the estimate of 38½ hours to pass through a canal 181½ miles long, with many sharp curves and 22 locks; also the estimate of 20 minutes to a lock; to fill or empty a lock in 12 or 14 minutes would not be a difficulty, but that is only a small part of the time required to pass a lock; it must be recollected that a vessel has to be "slowed down" long before she reaches a lock, and in most cases come to a dead stop before she enters the lock, then to be hauled in slowly and with care, for if a large steamer, weighing with cargo 8 000 or 9 000 tons, enters or approaches a lock with any amount of headway on her, she will probably walk through the lock without asking permission, and in much less than 20 minutes. If any such trade as would certainly be offered to a sea-level canal were offered to a canal with locks, there would, most undoubtedly, be great detention at the locks, by one vessel finding another vessel in the lock, other vessels ahead of her, gates shut, lock empty, &c., &c. If any one thinks these large vessels can be started and stopped, and turned like children's toys, let him go down to the piers in New York and see one of these large steamers arrive and get berthed. I arrived in July in the Britannic, and we were full one hour from the time we touched the dock until the ship was hauled into her berth. Taking my trip on the Suez Canal as a base for calculation, I would make the time of passing the Nicaragua Canal as follows: the speed was a mile in 25.2 minutes; 181.25 miles at 25.2 minutes per mile—76 hours; 22 locks at 1½ hours a lock, 33 hours; total, 109 hours; or, say 4½ days, and this may be put in opposition to one single day of ten hours in passing the clear, straight, unobstructed 30 miles of the San-Blas route.

Mr. Menocal estimates the cost of the Nicaragua Canal at 66 millions dollars. Men with experience and analytical brains have criticised this estimate and found it deficient. I agree with them, and further believe that the dimensions estimated are not such as a World's Canal calls for and should have, particularly in available width and depth, and more particularly when carelessly handled ships are to be encountered. In going

out of Marseilles harbor just one year ago in a straight channel of double the width of the canal proposed, our French captain had all his yards squared; he met an incoming brig, his vessel did not touch the brig by fifteen feet, but his main-yard struck the foremast of the brig and snapped in the middle, broke the fore-top mast of the brig, and down it came with all its spars close to the spot where I was standing with some ladies.

In pushing and preaching the merits of the Nicaragua route, there appears to be a fixed intention to ignore the San-Blas route entirely, and "pooh-pooh" it out of sight; they may knock it down, but it will come up again; they may throw cold water on it, but it will come out of the fire brighter than ever; they may build the Nicaragua Canal, but the San Blas will be built too, and then it will require no very wise man to tell which will be the one used. In the papers and estimates made out to compare the different routes, I see nothing said of comparative cost of repairs and maintenance; leaving the Panama route out as an absurdity, the lengths of the San Blas and the Nicaragua are as 1 to 6, but when it is considered that one is a sea-level canal, with good harbors and without locks, cut for a large part of its length through solid rock, the southern half in an open "savanna" country, the whole easily made safe from the ravages of floods and drains; while the other route is on and parallel to a tremendous drain, where floods occur that may and probably would sweep the whole works to destruction in a few hours; where earthquakes may and probably would twist the locks so that the gates could be neither shut or opened; where side streams, with their floods, must cross the canal to get into the main drain; where the time of transit compared to the San Blas is as 5 to 1; where there are no good harbors at either *terminus*, and where one *terminus* is a notoriously unhealthy place, I think any careful and critical mind would put the ratio of conservation of the two routes not as 1 to 6, but as 1 to 20 or 30, or more.

A five-inch rain falling in twelve hours is a thing not unknown in the Nicaragua lake region; as the water-shed of the San Juan River is 12 500 square miles, a five-inch rain is represented by over 4 000 millions of tons of water, a greater part of which has to find its way to the sea by the San Juan river, and not take a great length of time either; it was undoubtedly after one of these great rain-falls that the San Juan River, rising above its banks, overflowed, and cut the

Colorado River into the territory of Costa Rica. Those who are curious in the matter, might calculate the foot-pounds of energy or force developed by 4 000 millions of tons of water falling 107 feet, and its power for doing mischief.

Apparently the only objection to the San Blas route is its cost growing out of a long tunnel, and the inability to say what kind of material would be found in the tunnel. Let us examine this great bugbear, the tunnel, and compare it with other works.

The "Desaguadero" in Mexico, cut by the Spaniards, as a matter of precaution against floods, two hundred years ago, required about three times as many cubic yards of rock to be removed as would be required to cut a ship-tunnel 8 miles long, 180 feet high, and 80 feet wide. Now, if the Spaniards could do that two hundred years ago, should we, who have steam drills and wonderful explosive compounds, shrink in fright from a work of only one-third the size?

The St. Gothard Railway, now nearly completed in Switzerland, to connect the northern railway system of Europe with that of the South, is a work that involves immense difficulties. It has on its line forty-six tunnels, one of them at the summit being over nine and one-fourth miles long; one of them the engineer pointed out to me as being cut to secure the railway line from being buried by avalanches. Seven of these tunnels in complete circles of 1 000 metres diameter, are cut merely to get distance, and keep the gradient down to their fixed standard of 1 in 40 (132 feet per mile), and this tremendous work is being built for the very limited business of a railway. With this example staring us in the face, are we Americans, who boast ourselves of doing things with a bigger "auger" than our neighbors use, to turn tail and run away from a tunnel that would, if built, command the trade of the world, give us a grip on the trade of the whole Orient, allow us to manufacture all our own cotton and find a market for it in China, connect our Pacific possessions by a less expensive route than any railway can supply, consolidate our Union in stronger bonds, and lead in time to our becoming the most central and most powerful people in the world.

It has been objected to this tunnel, and reiterated by Mr. Menocal, that the rock found in it may be too soft, or of a character not fitted to support its sides and roof. This is all "moonshine." We know from mines and cuttings over all that country, and from surface rock that

crops out everywhere, just what we may expect; there is but one material existing that we may be afraid of, and even that was successfully overcome in the Box-tunnel of the Great Western Railway of England—I mean quicksand, and that we know we will not find under the rocks of the Isthmus. Mr. Menocal thinks we have not the data by which we can calculate the cost of the San-Blas Canal as fixed and clear as they have for the Nicaragua Canal. If they have not these data it is their fault; they should have got them; but I contend that we have all the data required, and more reliable than any data ever can be, on a line parallel to and close to a line of drainage, that Domine Sampson might call with truth, "prodigious;" we have the length of the whole route; we know what is tunnel and what open cutting; we know to a certainty that we can turn off all the streams and the one river, the Chepo or Bayano, and render them harmless to do evil. We know that we have good harbors on this route; we know that we have rock to contend with in fixed quantities, and, by estimating it as granite, we know that the estimated cost cannot be far wrong. It has been intimated that earthquakes might make a tunnel unsafe and dangerous; in answer, I would say that we have sixty-two tunnels on the line of the Oroya Railway in Peru, that many of them are completed and have been run through for years, and to this day I have never heard of any injury done to a tunnel on that line from earthquakes, which are much more frequent there than on the San Blas route.

We need not be afraid of striking a great vein of gold or silver, for in a case of that kind, unless the tunnelers become demoralized, such a vein might be coaxed into paying all or a part of the expense of the tunnel. This is not a speculation, unprecedented in facts, for my old friend, Genl. O'Brien, when forced by San Martin, the Liberator, to accept the Salcedo mine, in Peru (the richest mine at that time that had ever been worked), for his services in the wars of independence in Buenos Ayres, Chile, and Peru, struck a rich vein of silver in cutting an adit level from Lake Titicaca that paid all the expenses of cutting the tunnel for a long time. If some of the Bonanza kings of California could be induced to suspect another Comstock Lode on the line of the San-Blas tunnel, they would cut the tunnel for the fun of the thing, and thank you for the chance. But if we throw out the silver speculation and return to the "hard-pan" of a hard-hearted contractor's prices we may have the following estimate to stare in the face:

14 millions of c. yds. of rock in the tunnel above the sea level (the tunnel being 8 miles long, 150 feet high above the sea, and 80 ft. wide), at, say, $3 per c. yd	$42 000 000
4 millions of c. yds. of work in tunnel below the level of the sea (this part being 80 ft. wide and 30 ft. deep), at, say, $8 per c. yd	32 000 000
22 miles of open (earth and rock cutting) canal at the same price Mr. Menocal estimates his line from Del Medio to Brito, where it is all rock, at, say, one million per mile	22 000 000
Diversion of the Rio Bayano, say six times as much as Mr. Menocal estimates for the diversion of the San Carlos, $283 578 × 6	1 700 000
2 400 acres of grubbing and clearing, at $100 an acre, the same as Mr. Menocal estimates an acre at, this gives a width of 875 ft. for 22 miles, say	240 000
Diversion of other streams, all small ones, say	1 000 000
Light-houses, piers, store-houses, buildings of all kinds, say	1 000 000
Total	$109 940 000
Say	110 000 000
Add for contingencies 25 per cent	27 500 000
Grand total	$137 500 000

The above estimate is considerably above the estimate of Mr. Menocal for the Nicaragua route, but I will here venture to predict that it is very much nearer the truth of what the Nicaragua Canal will cost, if ever built, than Mr. Menocal's estimate. We may as well stare the truth in the face now as at any other time; it is the most honest way.

The people of the United States have had too much to do at home to look with much enthusiasm on works in distant countries or study with care the vast interests wrapped up in foreign trade; but the day is fast coming when they will be forced to know and value this matter, and then they will cut a canal through the Isthmus on the shortest route that can be found, no matter if there is a Nicaragua Canal or not. I am

glad to find that all of the old canal engineers that have ever visited the Isthmus, and made a study of this problem, join me in the opinion that the San-Blas route is the best for a sea-level canal, and the proper one to construct. And Mr. Kelley, who has spent his life and a fortune in surveys and study of this matter, and who has as clear an understanding of the whole subject as any man living, also most enthu siastically gives his adherence and support to that route as the only one that can satisfy the coming demands of trade, which is doubling up on us much faster than any one but those who study statistics could imagine.

As I feel convinced that the indirect benefit to the nation to be reaped from this canal is far greater than any direct benefit to any company, I would propose that the canal be cut, not on the line that is found to be the cheapest in first cost, but on the line that can be worked the easiest and quickest, and in the most reliable manner as regards line, level, repairs, and freedom from accident, even if it costs double the amount of the cheap and unreliable line. And in view of this end, I would, if I were the Government, offer to any company that would undertake this great enterprise, to *give* them one-half of the entire cost, and let them enjoy the rights, immunities, and profits of the whole thing, free of interest, for one hundred years; but reserving to the Government the right to take the whole at the end of one hundred years by paying one-half the original cost. It may not be out of place in this discussion to bring to the notice of the people of this day the prophetic writings of some who have preceded our time. Gouverneur Morris, the statesman, in a long letter, written in January, 1801, to John Parish, in Europe, says:

"As yet, my friend, we only crawl along the outer shell of our country. The interior excels the part we inhabit in soil, in climate, in everything. The proudest empire in Europe is but a bauble compared with what America will be, must be, in the course of two centuries, perhaps in one."

Robert Stephenson, the engineer, in writing to his brother-in-law (in London), when he was here in 1853, after speaking in the most enthusiastic terms of the progress and development of this country, says:

"Considering these circumstances, and looking at the boundless rich territories which are being opened and extended daily, I confess I am entirely at a loss to figure to myself the part which the United States

are destined to play in the world's theatre; their influence must daily increase and when her inhabitants reach the coast of the Pacific their power, must become predominent as a commercial nation." * * "Coal, which has hitherto given England her commercial superiority, is possessed by the States in almost incredible quantities; it has as yet scarcely been touched, because other sources of profit have presented themselves; but the day must arrive when, like England, the Americans will become a powerful manufacturing nation. If this be anything like the truth, how strangely must the relations between the civilized nations of the earth be changed—and then arises the question, so full of interest to an Englishman: Will England still maintain a good position in the struggle of countries, or will she, like other empires that have dropped into the past, begin to decline, and in her infirmity, like an aged parent, be obliged to look to her trans-Atlantic children for aid and support?"

We are fast arriving at the point predicted by Mr. Stephenson. We must have outlets for our products. In what direction can we turn for a market for our manufactured goods but to the shores washed by the Pacific and the islands of that great ocean? China and Japan, Australia and New Zealand, invite us to a close intimacy. The Spanish republics of the South American West coast offer us many tempting chances for trade enjoyed at present almost solely by England. The Orient and Occident of our own country wish to shake hands over a cheaper route of transport than any railway can supply. Let us mingle the waters of the Atlantic with those of the Pacific on the best, shortest, and most reliable route that Nature has furnished, or let us leave it entirely undone, for others of greater courage to accomplish.

I find in some of the discussions on this important problem that the San-Blas route is called impracticable, but in no case is an attempt made to demonstrate the impracticability. Surely it cannot be because it is so short, so straight, so free from floods, locks, dams, and aqueducts, or can it be that it is rejected on account of its having good harbors, and in a healthy region, free from swamps and lagoons. What can the claim of impracticability spring out of that blinds the Nicaragua promoters to the many points of merit of the San-Blas route unsurpassed and unsurpassable by any other route; there is but one point on this route that the objectors can fix their harpoons into, with any shadow of a chance of bringing it home to the minds of men as a dead fish. It is the tunnel; that is the bugbear, the stumbling block, that

narrow minds and unprofessional minds cannot climb over, creep under, or swallow whole. I am inclined to think that the tunnel is one of the best features of the whole route; it will cost, no doubt, a rousing big sum, but the amount will be a mere bagatelle to its value and importance, and when built it will be the surest and safest portion of the whole route; it will be through solid rock, and remain forever intact, requiring little or no repairs. The heading, a very insignificant part of the whole, would cost as much per cubic yard as any railway tunnel, but the balance down to the seawater level could, in that region, be done cheaper and quicker than an open cut of the same dimensions, where the average haul was the same, for the reasons that the men can work continuously without being driven off by the great rains that are so common on the Isthmus, and they can work, as in all tunnels, night and day. This tunnel can be cut cheaper per cubic yard than any railway tunnel could be in the same region, and for the reasons that the great width of the tunnel allows the men abundance of room to work in, and use all classes of labor-saving machinery; the force of the explosive compounds can be utilized to a greater extent, as there is more room for expansion. Any contractor can afford, and will afford, to take such an immense work at much less per cubic yard than he would think of asking for a small tunnel, such as are built for railways, for he can afford to procure and use the most perfect, extensive and efficient machinery ever used on any tunnel ever cut. I was shown at the St. Gothard Tunnel steam drills that by slow motion and high pressures would walk into granite as a knife would into cheese; there was nothing used on the Mount Cenis Tunnel to approach them in efficiency. I was shown air compressors that kept their great reservoirs night and day under pressures of 110 pounds to the square inch, and without difficulty; it was with difficulty and uncertainty that the air compressors of the Mount Cenis Tunnel could keep the pressure up to 60 pounds to the square inch. We are clearly a progressive race, and it would be a wise brain that could predict with certainty what advance may be made by some live Yankee in tunneling machinery when we come to cut a ship tunnel. I have copies of the entire maps and profiles of the St. Gothard Railway, and I have no hesitation in saying that they show the most complete and perfect surveys yet made for any public work ever attempted by man. There were 400 engineers and their assistants employed on these surveys, many of them highly educated and experienced men; their estimate of the cost

of this great work, 109 miles long, was 187 000 000 of francs; that was the sum placed before the public at the time the International treaty (of Germany, Italy and Switzerland) was signed, and a company formed to build the works, but they were only started when it was discovered, that, as usual, the works had been underestimated, and the cost was going to be swelled to 289 000 000 of francs, showing an error in the first estimate of 102 000 000 of francs. Where was this tremendous error made—in the great tunnel? No, for the estimate of that was 70 000 000 of francs. Monsieur Favre took the contract to build it at 50 000 000 francs, and if he had lived would have completed it in the coming year, without asking favors or assistance. There is an inference to be drawn from this statement of amounts, regarding estimates and costs of work in tunnels, and general work, which the intelligent reader will quickly see. Mr. Menocal estimates his great canal, 181¼ miles long, at $66 000 000; the St. Gothard Railway is to cost, for 109 miles, about $58 000 000; now, if the canal costs only as much per mile as this railway, it will cost about $97 000 000. The railway costs about $532 000 a mile, while Mr. Menocal estimates this great canal, with artificial harbors, great locks, but not large enough for great ships, great excavations of rock under water, great aqueducts and great dams, all liable to be swept out by the first great flood, and great embankments (sustaining a hydraulic head of 26 to 30 ft.) perched upon side hills, all of which may be washed out through the never-ending labors of rats and roots in boring holes, all, complete and ready to accommodate the trade of the world, at $346 000 a mile.

It may be claimed that the rock excavation under sea-water level is the impracticable point. If so, are not the excavations under water on the Nicaragua route equally or more impracticable. Let us stare some of the facts of this matter in the face. Nearly all of the excavation of rock under sea level on the San Blas route will be in still water, not affected by currents or winds or tide, while the same class of excavations on the Nicaragua route, in the beds of the San Juan and Rio del Medio, and in the bed of the lake, will be severely affected by currents in the river and waves and winds in the lake. To excavate rock in a swift current, such as is to be seen in the San Juan, is a species of fun engineers do not much covet. General Newton preferred to burrow under rather than attack the current at Hell Gate. Then, as to the work to be done out in the lake, I have an impression that this feature

has been very much under-estimated. Suppose we subject this to a few figures, from known data, at one point. It is to be regretted that there is no good hydrographic survey of this lake, so we must be content with such data as we can pick up. The history of this lake and river show that, some years ago, a certain Capt. Sheppard took his schooner from the Gulf up into the lake during a flood. He did this with great labor, by taking off his false keel and taking out his cargo, reducing the draft to about three feet. Once in the lake, he put on the keel, and, with the vessel loaded—drawing seven feet—he could not, in the dry season, get within two miles of San Carlos, at the upper end of the San Juan River. Now, taking this little piece of history to calculate by, and knowing the material to be rock, I make it that a canal only 100 feet wide (I call it 100 feet wide, not because that is enough, by three or four times, for the passage of a ship subject to the buffetings of winds and waves in a great lake and the canal out of sight, but because 100 feet is sufficient for the demonstration I wish to make), cut from the mouth of the river out into the lake, so as to have 28 feet of water all the way to deep water, will call for the excavation of about 1 100 000 cubic yards, which, at $8 a yard, will come to $8 800 000; but, for the sake of being generous and accommodating, suppose we call it the half of the above sum, and then it is six times as much as Mr. Menocal estimates as the cost of all the work to be done in the lake division, including mud and gravel, which, it is admitted, has to be dredged, and also the rock under water at the western end. Heaven only knows how much is required to be cut for a channel to get into the mouth of the Rio del Medio.

Let us return for a moment to the San Blas route, and take a fair, square look at the rock to be excavated there below the sea level. In the tunnel, where the great mass will be found, it may be dry, and it may not. Take it on the side of the "may not," and allow it to be as wet as ever was seen, is it supposable that any engineer in his senses, with but a smattering knowledge of hydrostatics, would attack it under water, when he can so easily build bulkheads, pump out the water, and work out the rock just as he did above the level of the sea. With this system of working kept fairly in view, I have a fancy that any intelligent man can see that this rock in the tunnel will come out more quickly and cheaply than will the rock in the bed of the lake, when the winds and the waves will be playing "hob" with the drilling machinery, and at times driving the men from their work. But suppose the work finished—who can esti-

mate the distress of mind of a captain when he finds his ship in a great lake with a wave-swell of 8 to 10 feet and only 2 feet of water under his keel; and that, too, only in a canal out of sight.

In my estimate of cost I dealt in big figures, and estimated for a depth of 30 feet of water. To bring this to the 26 feet of Mr. Menocal's section, there should be deducted over $4 000 000. Then again the tunnel, on more accurate surveys being made, may be reduced to six miles instead of eight. This would reduce my estimate again by $15 000 000, and then the 25 per cent. for contingencies would come down some $5 000 000, making in all some $24 000 000 of reductions. But I prefer to let it stand as I had it, at $137 500 000, and time will show who comes nearest to the truth, for it is in my eyes a sure thing that a great world's canal will some day be cut on the San Blas route.

As the transit of any of these canals will have to be suspended during the night, and as the San Blas route is so short that it can be navigated from end to end in ten hours, or less, and as one passing place (at south end of tunnel) only is required, the whole of the rest of the canal can be made. and should be made, much narrower than would be allowable and required on the Niacaragua route, where passing places must be frequent and provided between all the locks.

As sailing vessels are destined to form a great feature in the traffic of this Isthmus Canal—a feature that the Suez Canal is entirely deprived of—I beg to refute the claim made by the Nicaragua projectors, that the Bay of Panama is difficult to get in or out of on account of calms. I have been at Panama for weeks—I have been a guest on board of a United States war vessel for two weeks in that bay—and I never saw a day when a vessel was detained there, or prevented from coming in by either calms or storms.

New Yorkers would feel very indignant if told that their port should be shunned on account of its being difficult to get in or out of, and yet, I suppose, they all know that sailing vessels have often been for days outside, afraid to come in, and for days, in the lower bay, afraid to go out, during times of storm and fog—two hygrometric and meteorological features never met with in Panama Bay. Let us place the "calm" claim alongside of the "impracticable" claim, and send them both to the safe keeping of croakers. Intelligent men of this age are not going to take much stock in those two articles of Nicaraguan faith.

In getting from our shores to China and Japan, the great objective

points, we as a growing commercial nation should look with much respect and admiration on the pacific character of the Pacific Ocean. The Spaniards of old used to say that all a "skipper" had to do on leaving Panama for the Phillippine Islands was to set his course, tie his rudder fast, go to sleep, and not wake up until he reached the end of his voyage. Ships going from Panama to China can take a trade wind going and a trade wind returning. When the canal is cut, and we have a new highway to the East, this feature will play an important part in assisting us to the largest share of the trade and traffic of the Orientals—a trade which for centuries heaped wealth into the coffers of the Greeks, the Jews, and the Armenians of the Mediterranean—a trade that England seized and grew her wealth and power out of, when Vasco de Gama showed her a new way to the East by the Cape of Good Hope, four hundred years ago—a trade that is destined to fall into our hands and give us wealth and power such as no nation ever held, as soon as we can muster courage enough to cut an Isthmus Canal on the shortest route that can be found, and throw it open for all the world to enjoy as best they may.

It may not be inopportune to mention in connection with this discussion that a late commanding officer of the United States Navy, now living in Washington—a gentleman well acquainted with Nicaragua, Panama, and the Pacific Ocean—once said to me: "I should be very loath to allow any ship I commanded to be run in a canal and locked up a hundred feet above the ocean. I should be afraid of never getting down again."

In connection with the risks run by placing a big body of water on the side-hill slopes of a river valley (in a region of great rains) in a prism made of cuts and embankments, crossing spurs of hills and ravines, and also to show the fallibilty of man's estimates, I beg to mention a little incident that occurred on the line of the Oroya Railway, in Peru, in the Valley of the Rimac. The final location had been made, and for some time the construction of this railway had been going on in a region almost rainless. At a point in the valley where the line crossed the mouth of a ravine we had left an opening to be filled by a bridge of 100 feet span. At the head of this ravine some poor *peons* had been cultivating the soil on the top and side of the mountain by bringing the water of melted snow from other and higher mountains for irrigating the land, as water in many parts of Peru is valued like gold. The peons, with great

labor, puddled and protected the edges of their "chacras" so as to prevent loss by waste. The water sunk into the soil, and permeated down deep through stratas of alluvium, gravel, clay, and loose rocks. This was close to and on the side hills leading down to the Valley of the Rimac. This gradual permeation of rock and gravel, clay and sand, with water had, no doubt, been going on for a long time. The water was trying to find its lowest level. The rocks and the earth were only waiting to be released from the bonds of cohesion that had held them on the mountain side for ages to show what attraction of gravitation could do. Day by day this insinuating element, water, was doing its work, in the dark and in the night. Ceaseless, unopposed, all powerful, it was cutting and severing the bonds of cohesion. The people in the valley in front of the ravine rested in quiet content. The peons of the mountain imagined no evil genius underlying their crops, but in a moment when no one suspected danger the whole mountain side started for a race to the valley. Five millions of cubic metres (about ten millions of tons) of rock and earth, gravel, mud, and water came rushing into the valley, crossed its whole width of 1 400 feet, surged up against the opposite side, rolled over and crushed out of sight all the houses in its annihilating course, and filled the valley with a dam 1 600 feet wide on the bottom and 108 feet deep. The average vertical fall of this vast body of earth was about 1 500 feet, and the horizontal movement over 5 000 feet. Surely water has power, and we are entitled to place it with its sister element, fire, as good servants but dreadful masters. Gouverneur Morris, the projector of the Erie Canal, proposed that it should be built without locks, and on a line that would give it a uniform descent per mile from Lake Erie to the Hudson River. What a magnificent idea. It was too magnificent for the time. A line of this kind would carry the canal to the south of Cayuga and Seneca Lakes. With fifteen millions of tons of surplus grain in the far West seeking a market on the Atlantic seaboard, it would soon make New York the imperial city of the world, if it could find its way by water lines, without one check or hindrance, from the great grain fields to the great city.

A canal built as Morris proposed would not have a greater descent per mile than is now existing in the Ganges Canal in India, which has a fall of fifteen metres to the mile, and is navigated in either direction with facility and certainty. I mention this canal and its gradient to show that even a guard-lock is not a necessity at the south end of the San-

Blas route to provide for the current that would be created in the canal at extremes of high and low tide of the Pacific, but a guard-lock there would be a convenience and an economy.

Discussion by FREDERICK M. KELLEY.

It is very gratifying to notice the lively interest being taken by the civil engineers of our country in this question, as they by profession, education and experience are the only class competent to make surveys, locate the canal, estimate the cost, and manage it when constructed; hence, they ought to take a prominent and leading part in the discussion.

With all due respect to the intelligence and ability of naval officers to build and sail ships on the ocean, their want of experience and knowledge in constructing railroads, canals, bridges and other great works on land, makes them comparatively incompetent to decide so great a question as a inter-oceanic canal. It is true that some, if not all, the late Government expeditions employed more or less civil engineers to run the lines, but the chiefs in command were naval officers, whose orders they were bound to obey.

The navy part of the Lieutenant Strain Expedition in 1852, and Captain Craven's in 1858, were failures, and of Commander Selfridge's surveys I have always regretted that he, so well supplied with government instruments and men, did not go over the entire route, instead of making only a partial and hasty examination, and thus throwing doubts and uncertainty on much the shortest of all the sea-level routes with its good harbors and longest slope of open cutting on the Pacific, the dryest side of the Isthmus.

The facts are, the San Blas route has good natural harbors at both ends, requiring no improvements or breakwaters whatever—is the shortest, best and cheapest sea-level route known—is about 30 miles long, and with the exception of the Atrato-Napipi has less material to remove than any other route, and the canal when built will cost very much less to keep in repair, and will afford the greatest, quickest and cheapest facilities for all kinds of ocean steam and sailing vessels to pass the Isthmus for centuries to come.

That is what the commerce of the world demands, and will finally have, cost what it may.

Mr. Menocal says the San Blas Canal will cost twice more than the

Nicaragua Canal, and he might have added it will be worth three times more in consequence of the less cost of maintenance and the greater facilities it will afford for the passage of large ships.

The Nicaragua Canal advocates say that locks are used all over the world. So, it may be said, they are condemned all over the world.

Every engineer avoids them, if possible, knowing they are tedious, expensive things to keep in repair even in our mild, dry climate ; but in the excessively wet and flood-water, iron-and-wood-decaying climate of the Isthmus, they would indeed be very expensive structures to keep in order for the passage of large ocean vessels.

Locks to canals are what high grades are to railroads, most expensive and difficult obstacles to overcome. Chiefly on account of high grades, the expense of running the Erie Railroad is about 70 per cent. of its receipts, while on the New York Central R. R., where the grades are easy, the running expense is but about 50 per cent. of the earnings, and the difference of 20 per cent. in favor of the latter road pays large dividends to its stockholders, while the Erie has paid nothing to the stockholders for many years, and there is no telling when, if ever, it will earn a dividend.

I have no faith whatever in the durability of earth embankments along a ship canal on the Isthmus. The heavy rains in that country will wash them into the canal, hence I have always maintained that the more miles of rock the canal passes through the less walling will be required to keep the banks from caving in—the more solid and durable will be the structure, and the less it will cost to keep in repair.

If the canal is excavated through 60 miles of earth, 120 miles of something besides dirt will have to be substituted to keep the banks from falling in during the heavy rains.

Even on our New York State canals the embankments are watched with jealous care, and notwithstanding the use of steamboats to lessen the expenses and increase the speed of transportation has been urged again and again, still the authorities hesitate for fear they will wash the banks.

It strikes me that every sensible man must see at a glance that a canal even 200 feet wide, located in the tropics, where the rains fall in torrents, the like of which is unknown in this country, and having great ships with their tugs passing through and washing it daily, must have something more solid and substantial than earth to keep the banks from caving in and filling up the canal.

Even the natural banks on the Atrato River, the formation of centuries, and on which grow all sorts of tropical trees and vegetation, giving something like stability to their character, are honeycombed with holes and crevices its entire length, and through these the water rushes whenever the river rises and falls during the rainy and dry seasons, carrying down endless quantities of silt to be deposited on the bars at the mouth, like the Mississippi.

This is one of the important reasons why I advocate the San Blas route.

Of the 29 389 828 cubic yards to excavate or remove on that line 25 543 939 cubic yards is rock and the remaining 3 955 889 yards is earth.

On this point and the tunnel question, when discussing the San Blas plans at the Paris Canal Congress, in May last, Mr. Favre, the St. Gothard Tunnel engineer and contractor, said: "I take the same views as Mr. Ruelle, and like him I prefer tunnels to ditches and river navigation. The construction of a tunnel would give place only to expenditures well known, and which could be determined in advance. One could work in a tunnel without interruption, and the rains would cause no embarrassment nor delay. The security of the work would be complete, and there would be no fear of caving in.

"In consequence of all these considerations I do not hesitate to give "my preference to the canal terminating in San Blas Bay in spite of the "tunnel of 10 miles which that project would require."

It will be borne in mind Mr. Favre *supposed* that Commander Selfredge's *opinion* of the tunnel being 10 miles long was correct.

Sir John Stokes, on the same occasion, said: "As for me, I give my "preferences to the San Blas project," and on another occasion, returning to the subject, he said: "The project in question (San Blas) would "avoid several obstacles and solve advantageously several difficul-"ties. * * * *

"Besides, nothing would be more easy than to give the canal a mouth "independent of the Bayano, and thus avoid the very inconveniences of "which they had been speaking."

Mr. Conrad, the Holland engineer, also advocated the route.

The opponents of the San Blas route estimate the tunnel at from 100 feet to 125 feet wide, and from 140 feet to 150 feet in height, above canal bottom, and thus succeed in swelling the cost of the work to almost fabulous sums.

This is very unfair, in view of the fact that at least 95 per cent. of all the vessels engaged in the Pacific trade measure less, and not more, than 40 feet in width of beam; hence a tunnel constructed 80 feet wide at the water line, and 125 feet high above the bottom of the canal, will afford ample room for ships by striking their topmasts and hauling yards around to pass, and outside of the tunnel, where the canal is estimated 125 wide and 28 feet deep, there is abundant room for two large ships to pass each other.

Besides, the route is so short, there is no necessity for building the canal wide enough for two ships to pass each other, as going at the rate of three miles per hour 100 ships can be towed one way in ten hours, the same number back in the same time, and thus 200 vessels would be able to pass the Isthmus at this point in 24 hours.

No long-lock route could afford those accommodations in so short a time.

If a canal should unfortunately be constructed *via* the long 181 miles Nicaragua route, with its bad harbors requiring constant dredging and improvements to keep open, and encumbered with 18 or 20 locks, and as many more duplicate locks, making in all 36 or 40 locks, which will demand "eternal vigilance" and constant expense as the price of safety, it will prove so expensive, dangerous, and tedious that the ever-expanding wants of commerce will demand and execute a deep, wide, and short *sea level-canal*, through which ships can pass cheaply and quickly, on an even keel; then there will be two canals, and it needs no prophet to predict which will become worthless, and remain as a stupendous monument of engineering and financial folly.

The heading in the San Blas tunnels amounting to 332 640 cubic yards, is estimated at $20 per yard.

The breakdown, amounting to 10 090 080 cubic yards, is estimated at $5 per yard.

Open rock cutting, amounting to 15 011 219 cubic yards, is estimated at from $1 75 to $2 50 per cubic yard.

Earth excavating, amounting to 3 955 889 cubic yards, is estimated at from 50 cents to $1 per cubic yard.

The masonry, of which there is 54 446 cubic yards, is estimated at $15 per cubic yard.

Concrete at $7 per cubic yard and pumping at about $2 000 000.

The whole work complete from sea to sea at $104 017 780.

If the tunnel should require lining its entire length, which the firm character of the rock does not indicate, then about $32 000 000 will have to be added to the above sum.

It is true the tunnel is one of large magnitude, and for that reason will afford much more light, room, and air for blasting operations than an ordinary railroad tunnel, and driven at both ends with steam and compressed air-drills, and other improved mechanical appliances, which will be brought into successful use as the work progresses, it can be constructed and maintained with less engineering skill than damming and locking, opening, and keeping open, the harbors of the Nicaragua route.

In view of the wonderful engineering achievments all over this country and Europe, and the success of the Hoosac, Mont Cenis and St. Gothard tunnels, and still greater ones being seriously planned and proposed under the Simplon Pass, in the Alps, and under the Straits of Dover, 20 miles long, between England and France, I can see no reason why engineers should recoil before the San Blas tunnel, which is not so long by several miles as the three last alluded to.

When the work is done we will have a deep, wide, sea-level canal through the narrowest part of the Isthmus, with good, natural harbors, easily approached on a wide open sea, permanent and durable as granite itself, fully satisfying the wants of the commerce of all nations, and which will remain a lasting monument to engineering skill and perseverance.

Discussion by CHARLES A. SWEET.

SAN BLAS ROUTE.

The route for the San Blas line was surveyed from Chepillo Island, in the Bay of Panama, to within about two miles of the Gulf of San Blas, where, by the hostile force of the Indians, and the desertion of our own men, we were compelled to return to the Pacific slope. The northern or Atlantic terminus of the proposed tunnel was located two days before, and all other salient points of the proposed canal, except at the Atlantic coast, were similarly obtained.

The limits of this paper will not permit as full a description of this route as may be desired. I will, therefore, give only the principal points of interest, trusting that the Society will allow me, in the near future, a

more extended article on this subject, thus completing the *official* data of all the favorable routes.

The total length of canal, from the Island of Chepillo, in the Bay of Panama, to 28 feet depth of water in the Gulf of San Blas is $30\frac{3}{100}$ miles, for ten miles of which the Bayano river is to be utilized.

The length of tunnel was fixed at seven miles, to have the following dimensions: 70 feet bottom width, a batter of 1 in 12 to 54 feet above, whence springs the arch, giving a total height of 118 feet, and a total area of 845 square yards. The tunnel is intended to pass but one vessel at a time, which can be easily done in two hours.

The section of the open work, in rock, is to be 100 feet width of bottom, a batter of $\frac{1}{4}$ to 1 to 32 feet above thence an offset or bench of 10 feet in width, with the same batter through the rock; thence a slope of 2 to 1 through the earth to the surface. On the Bayano river a channel of 200 feet in width was estimated for. Depth of water throughout, 28 feet.

The Gulf of San Blas furnishes a magnificent harbor on the Atlantic side, and the Bay of Panama is unsurpassed on the Pacific. The extreme rise and fall of the tide in the Bayano river, at the divergence of canal, is $12\frac{86}{100}$ feet. The tides on the Atlantic side are from $1\frac{1}{2}$ to 2 feet from ebb to flow. The mean half tides of the two oceans are on a level. The plan of construction was a tidal lock at the Bayano river, and a dam across said river by which the water surface in the canal could be maintained at ordinary high tide, and to terminate at the Gulf of San Blas with a lock of nine feet fall. The locks to be 450 feet between mitre sills, and 60 feet width of chamber. Total estimated cost, including 25 per cent. for engineering and contingencies, $104 017 780; annual repairs or maintenance, $100 000.

Time in transit, from ocean to ocean, for sailing vessels.

13 miles of open canal (no locks), at 4 miles per hour	$3\frac{1}{4}$ hours.
7 " " tunnel, at 3 miles per hour (say)	$2\frac{1}{4}$ "
10 " " river (av.), 4 " "	$2\frac{1}{2}$ "
2 locks, 30 minutes each	1 "
Total	9 "

PANAMA ROUTE.

From all the surveys, and my knowledge of the country, I am forced to conclude that a canal between Aspinwall and Panama, either with or

without locks, is impracticable, as I cannot see how it is possible to prevent the flood waters of the Chagres, which drains a large area of an annual rain fall of 137 inches, from overflowing and destroying the usefulness of the canal. The line crosses that river several times, and to construct a new channel for its waters would cost more than the whole canal, with much doubt of its permanency. I will add here that no such objection exists on the San Blas line.

There is only an open roadstead at Aspinwall, and the periodical "*Northers*" create sad havoc with the shipping, and destroy the strongest wharves that have been built there.

Mr. Menocal was the Chief Engineer of the Government Survey of this route for a *lock* canal, and the estimated cost of $94 511 360 was based on the following prices :

Excavation in rock	$1 25 to $1 50	per cubic yard.
" " earth	35 "	" "
Embankment	15 "	" "
Concrete	8 00 "	" "
Excavation in tunnels, for feeder	4 00 "	" "

Which, evidently, is about one-half what it would cost.

Nicaragua Route.

From Mr. Menocal's paper it seems that the size of locks, and depth of canal, are intended for about the largest ships in the Pacific trade, while the width of channel would not permit, even on a tangent, two vessels to pass each other having over 36 feet beam. Possibly, it is intended to have turnouts for the larger class of vessels, but no mention is made of it, and yet he assumes, in the computations, vessels 400 feet long and drawing 24 feet of watsr. The middle ordinate of 400 feet on a curve of 2 200 feet radius is nine feet. This, of course, must be deducted—once, from the bottom width, leaving 63 feet available, or two vessels of equal beam cannot be over 31½ feet The width of six feet on the two slopes are left for an easy passage. On a curve of 2 500 feet radius the ships could have but 32 feet beam; 3 000 feet radius, 32⅔ feet; 3 500 feet, 33 feet; 4 000 feet, 33½ feet, and 5 000 feet radius, 34 feet. To increase the width of canal 50 per cent. there should be added ⅓ to the quantities, and the necessary width on river and lake should be 150 feet on the former, and 200 feet on the latter, which would increase the quantities, say, one-half, making a total increase to his aggregate estimate of $16 633 924, or a total cost of $82 356 071.

If the prices assumed are no greater than was used on the Panama line, a still larger amount should be added. Taking all these contingencies the total cost of construction would be as large as that estimated on the San Blas. The annual repairs or maintenance of canal would be in proportion to the length of line and number of structures. On this basis should tolls be charged. Estimated annual repairs, $1 000 000.

The estimated time in passing a vessel, from ocean to ocean, not counting detentions by accidents to the numerous structures, which must be expected, should be controlled by the lengths of levels, or distances between locks. No vessel can get a headway of four miles an hour between some of the locks as located on this line. Practically, the time would be for a steamer, in this particular line, with its numerous short curves and levels, as follows :

62	miles of canal, at	2	miles per hour			31	hours.
63	" " river, "	4	"	"	(say)	16	"
56½	" " lake, "	8	"	"		7	"
21 locks, 20 minutes each						7	"
					Total	61	"

For sailing vessels with tugs it would take 81½ hours, or say 3½ days.

Discussion by JOHN C. CAMPBELL.

In the paper presented by Mr. Menocal on Inter-Oceanic Canal Projects, he assumes that the Isthmus has been sufficiently explored to enable us to determine the difficulties that would have to be met in the construction of a ship canal at the several places pointed out as presenting favorable indications for execution; then, giving certain data, concludes, that while a canal with locks seems to be practicable *via* both Panama and Nicaragua, the latter route possesses greater facilities for the execution of the work at a reduced estimate of cost, based on sufficient information to eliminate unknown elements.

The first question to be decided is, has there been sufficient explorations and instrumental surveys made to enable capitalists to invest their money in the building of a ship canal between the two oceans upon either of the proposed routes. I do not think that such knowledge exists or has ever been obtained.

Across the Isthmus of Tehuantepec a survey for a ship canal and railroad was prepared for, and Major Barnard of the United States En-

gineers was placed in charge. The survey was commenced and vigorously prosecuted, but in the tropical regions, where the forests are dense, much of the country uninhabited, with no other than mule paths for roads, anything like an accurate survey must be, from the nature of the case slow, requiring much time to obtain the knowledge sought for. This survey was begun in December, 1850, and in June of the following year (1851) the engineers were ordered out of the country by the Mexican Government. Some further examinations have since been made, but no instrumental surveys, across the Isthmus at this point.

In 1850 the Nicaragua Transit was established across Nicaragua, between Greytown on the Caribbean Sea and San Juan del Sur on the Pacific Ocean. Small steamboats were placed on the San Juan River and on Lake Nicaragua, and portages established around the rapids in the river, and between the lake and the Pacific a wagon road constructed, over which a part of the time during which this route was used, passengers and baggage in wagons were transported. The boats were in 1855 seized by the filibusters, and the route abandoned by the Transit Company. In 1851 Col. Childs made a survey for a canal on this route, but no work was done in construction. Now we have another survey by the United States Government, under the direction of Commander Lull, made by Mr. Menocal.

At Panama a charter was obtained by Mr. John L. Stevens for a railroad, a company organized, and Major Hughes selected to make the survey, to enable the company to decide upon the most practicable route. A party was sent down to San Blas, where an interview was had with the Indians who occupy the Isthmus between Porto Bello and the mouth of the Atrato River, but failed to obtain permission to make the survey. Major Hughes made a survey of the Chagres River and of the mule path between Gorgona and the City of Panama. In 1850 the work of constructing the railroad was, under charge of Col. Totten, commenced, and in 1855 was opened for traffic between the two oceans. This route, having been occupied for thirty years, the topography of the country and its facilities for the construction of a canal, either with or without locks, are well known.

From the line of this railroad to the mouth of the Atrato River no instrumental survey extending across from ocean to ocean has ever been made. Lieutenant Strain of the United States Navy, accompanied by commissioners of the New Granadian Government, attempted, in 1854,

to make a survey from Caledonia Bay to the Gulf of San Miguel on the Pacific Ocean. They procured Indian guides, but the guides, after leading them into the wilderness, deserted, and the party was lost in the jungles. Several of the party, including one of the commissioners, died from fatigue and starvation in this attempt. Gisborne, Cullen and de Puydt, at different times made reconnaisances, but no instrumental surveys were made.

Between the Bay of San Blas and the Bay of Panama an instrumental survey was made in 1864 for Mr. Kelley of New York, from the Bay of Panama to within three miles of the Bay of San Blas, but the party was there met by the Indians and driven back. Commodore Selfridge's party, in 1871, made an exploration from San Blas to a point where they found stakes planted by Kelley's surveyors. Evidence was obtained by Mr. Kelley's engineers to approximate the length of tunnel on this route, but Commodore Selfridge's exploration of one end of the tunnel line led him to decide that the length would be three miles more than was deemed necessary by those who surveyed for Mr. Kelley across the dividing ridge.

Here, for a distance of over one hundred miles, is the narrowest part of the Isthmus of Darien, across which no careful survey has ever been made, and until such survey is made it is really unknown where the best place is for a tide-level canal to be made.

Mr. Menocal furnishes the data on the Nicaragua route, as taken from his own survey: and the quantities we cannot question, though we may his prices and conclusions.

He says of the Panama route, the mean annual rain-fall is 124 inches, while that of the Nicaragua route he places, he says, "approximately, at 52 inches on the Pacific Slope and 85 inches on the Atlantic side.

This statement is incorrect. The rain-fall on the Pacific Slope, it is well known, is much less than on the Atlantic, and he so states it on the Nicaragua route. The rain-fall given is as measured at Aspinwall, and the comparison should be given with that falling at Greytown, similarly situated on the Caribbean Sea, but instead he compares the rain-fall at Aspinwall with that at Granada, some 150 miles distant inland, giving it, he says, approximately. In relation to this matter Col. Totten says: "The large mean annual rain-fall is a serious obstruction to work, but not more so than along the San Juan, where, according to the reports I have heard from there during a residence of twenty years at Aspinwall, more rain falls than on the Chagres." One has only to look upon

a map of the Isthmus and examine the positions of Chagres and Greytown to see that this must be so.

Mr. Menocal says: "It is to the discussion of the most prominent features of the Panama and Nicaragua routes and their relative advantages and disadvantages to which I will confine myself."

The first question in such a discussion is, however, what kind of a canal shall be adopted, one with locks or one without. If the latter, then the Nicaragua route can no longer enter into the comparison.

The general opinion of the members of the Paris Congress gave the preference to the Panama route over the Nicaragua route either with or without locks.

We can only compare the two with locks. As a lock canal the Panama route offers the advantage of distance, using Mr. Menocal's figures, in the proportion of 42 to 181—an equal or lower height of summit level, less cost of construction, and better harbors.

Mr. Menocal says that the cost of a canal on the Panama route will be much greater than on that of Nicaragua.

In his paper we find no estimate of the quantities of excavation for a lock canal by the Panama route, he giving them for a tide-level canal, but not for a lock canal; but he gives the quantities calculated on the cross section recommended by the Paris Congress, as on the Nicaragua route at 70 781 555 cubic yards of excavation, and on the Panama route, on the Paris Congress cross-section, for a tide-level canal, as calculated by him, 73 925 230 cubic yards, or 4½ per cent in excess of the Nicaragua lock canal, he here keeping the same cross-section. To the Panama route is to be added the cost of the channel for diverting the Chagres river and its tributaries from the canal, which he says the committee of engineers at the Paris Congress estimated would cost $8 400 000.

Taking Mr. Menocal's figures, we have a tide-water canal at Panama with 4½ per cent. excess of excavation, and $8 400 000 for diverting the Chagres river from the canal, with the advantage of 42 miles of canal as against 181, as against the cost of locks on the Nicaragua route between points where there are no harbors at either end of the proposed canal.

Canal on the Panama Route with Locks.

Mr. Menocal locates the crossing of the Chagres river, by the lock canal at Matachin, at which point he fixes the summit level as necessary to give clearance to freshets in the river at 123.75 feet above tide. This

elevation of the summit is unnecessary. A good crossing can be had below Gorgona and another near Barbacoa.

At Barbacoa the railroad crosses the river at an elevation of 62.50 feet above tide, and with a length of 625 feet, and has passed all the water of that river safely for the last twenty-five years, except the last November freshet, when the water rose to thirteen inches below the track on the bridge. Taking his figures, the summit level would be here 108.50, but this height would not be necessary. He makes no allowance for the water-way of the arches, and estimates for an aqueduct 1 900 feet in length. From his statements in regard to the feeder, I think no very careful survey could have been made when he found it necessary to locate 7 tunnels and two siphons on the bank of the river in 10¼ miles.

To make these statements is sufficient to show that an engineer in two months time cannot carefully locate a ship canal of forty-two miles in length and a feeder of 10¼ miles without drawing very largely upon the imagination. He estimates the cost of 16 culverts and the necessary side drains, at $18 331 343, while on the Nicaragua route for 45 miles of canal along the San Juan river he estimates the cost of the drains at $340 000, though this 45 miles is all in the San Juan valley, a distance greater than the whole length of the canal on the Panama route.

Mr. Menocal in his paper further says of the Panama route, there is a total lack of building materials of all kinds fit for the construction of the works recommended. This is a discovery that no other man has made. The Panama Railroad has a number of bridges, all with stone piers and abutments, and it is a new idea that walls cannot be built with stone suitable for bridge work.

One great advantage the Panama route has over any other is the facilities it has for obtaining men and supplies, and their prompt and rapid distribution over the line of work. With regular lines of steamers to Aspinwall and Panama, any and all supplies are at all times readily obtained, and the railroad built to distribute them.

With his figures for the quantities of excavation for a tide-water canal on the Panama route, as only exceeding the lock canal on the Nicaragua route by 4½ per cent., we need not seek further for reasons for not giving quantities on a lock canal on the Panama route.

Colonel Totten built the canal of the Dique between the Magdalena river and Carthagena, also the Panama Railroad, with which work he was connected for twenty years. He should know the cost of work in

the tropics, and the advantages furnished to parties building a canal on the Panama route by the railroad across the Isthmus at this point.

He estimates the cost of a lock canal on the Panama route with a width of bottom in earth of 72 feet, and in rock of 80 feet; slopes in earth 1 to 1, with walls for protecting slopes, and slopes in rock ½ to 1, and with 28 feet depth of water, at $83 381 110. He estimates the same quantities, at Mr. Menocal's prices, at $42 364 248.

The kind of canal to be built is to be decided by those who build it, not by us here. The cost must, of course, enter into the question of choice, but as expressed in the Paris Congress, a canal without locks will be preferred at a very large cost over one with locks. A short canal is to be preferred at a largely increased cost over a long one. If we now combine the two advantages of a short canal without locks, it is incomparatively to be preferred to a long canal with locks.

The question whether any other than a tidal canal shall be built is one of great moment, and we must not be carried away with the statements of what can be done with a canal with a depth of 26 feet of water and with locks of 400 feet in length.

Steam transportation has been introduced in the last forty years, and has already revolutionized the commerce and business of the world. In former times, famines occurring, whole provinces were decimated. Now, a scarcity occurring in England, the Mississippi valley sends her crops by the railroad to the ocean, where steamers promptly deliver it at the desired ports. Russia aids, by her yet few roads, in delivering her crops on the Black Sea and the Baltic, to be forwarded by steamers, while California, Oregon and Washington Territory send by sail around Cape Horn, they yet waiting the great Inter-oceanic channel yet to be made across the Isthmus of Darien for steam transportation. Almost as great difference now exists in ocean transportation between the iron propeller, with its many water-tight compartments, and the old method of conveyance by sail, as exists between the transportation by coach and wagon and the railroad. Economy in transportation on the ocean is steadily being reached by the increased carrying capacity of the steamers, and the skill developed in generating and utilizing the powers of steam. Very many of our steamers leaving New York for Europe are over 430 feet in length, and drawing 26 feet of water loaded, and others are being built of over 500 feet in length. Is it a wise or far-seeing policy that shall now, in this age of progress, with steamships making such strides

in their carrying capacity, build a canal of such limited capacity as is proposed on the Nicaragua route, and thus limit the market of the States bordering on the Pacific. I do not believe that it is.

There is another point I wish to call to the attention of the Society, and which I have not heard dwelt upon, that is, that a canal across the Isthmus at Panama, while it will as well accommodate the business from the Atlantic ports, will, at its terminus at Panama, much better aid the trade between the Atlantic ports and the west coast of South America. Most of that trade now goes around Cape Horn, from which point it is as near Europe as New York.

The travel and light goods between the Atlantic and Pacific coasts of North America will be carried by rail across the continent. We have now one railroad completed, and three others in rapid progress toward completion. Canada has one in progress, and in a very few years Mexico, Honduras and Costa Rica will have completed roads, now in progress of construction.

What the steamer requires is the open sea, and when that cannot be obtained, a short canal, broad and deep, and without locks.

Whether it shall cost one hundred or two hundred millions of dollars is of no moment. If built in the proper manner, with wide channel and free from locks, its business will astonish the world by its magnitude, and its success, as a monetary investment, will be only limited by the judgment and conscience of those who control it.

Discussion by CHARLES D. WARD.

I will not attempt to discuss the general question of where the canal should be located, thinking more surveys are necessary before that can be done intelligently, but confine my remarks to the proposed canal with locks, from Colon to Panama, described in Mr. Menocal's paper, and more fully in the report of Commander Lull.

The question in my mind is, have they proposed the best plan for the canal on that route. Have they not possibly been frightened by the great rise of the river in floods, and without due consideration of the subject, taken it for granted that the Chagres River *must* be crossed by a *viaduct*.

I think it very feasible to dam the river and cross in slack water, and thereby save the viaduct and lower the summit level forty feet.

The bottom of the Chagres valley is so narrow that in floods the

river rises thirty-six feet, and attains a width of 1 500 feet, with a sectional area of 15 000 square feet. These figures give an *average* depth of water of but *ten feet*, which shows that if a dam was built with an overfall 1 500 feet long you might expect ten feet depth of water to pass over it. But Commander Lull states in his report :

"The extreme height attained by the water in time of freshets is due, to a *considerable extent*, to the backing up of the water from below, and could be *very largely* prevented by clearing off the timber in the short bends of the river below."

We cannot say how much this back water helps to raise the river, but I think we can safely assume that the dam would reduce the extreme rise in the river to *less than ten feet.*

The summit level would have the same elevation as the top of dam.

The reservoir formed by the dam would be ten miles long, and serve as an equalizing reservoir, and during floods would be entered from the summit level of the canal through guard locks, one on each side, which would be left open, of course, when there was no flood. Navigation across the reservoir would be easy, as the rate of flow of the current would be reduced from seven to three and a half miles per hour, the sectional area of the stream having been doubled by the dam.

I have estimated for a dam forty-four feet high, giving the summit level an elevation of eighty-four feet above tide water which is forty feet lower than Commander Lull's summit.

The advantages of my proposed plan I conceive to be: the saving of a feeder ten and one-fourth miles long, with syphon, dams, tunnels, &c.; an abundant supply of water, which is doubtful at the head of the feeder, but at the lower end of the reservoir we would have 120 square miles more of drainage area; saving the building of four locks and generally the time in passing through six less locks and finally save a viaduct 1 900 feet long and eighty-four feet high.

The rock cut at summit would have to be made forty feet deeper, and the dam built across the river, but from figures given in Commander Lull's report I have estimated that what would be saved on locks, feeder, aqueduct, &c., would pay for that extra work, and the cost of the two plans would be the same.

There would be but seventeen locks to pass through generally, but during floods nineteen. Commander Lull's Panama plan has twenty-five. The length, of course, would be the same in both.

Might not this plan, with its low summit level and few locks, be the happy medium between the expensive sea-level plans and the cheaper, but longer and more elevated routes, with a larger number of locks.

In conclusion, I would say that I should be very glad to hear the views of the engineers that are personally acquainted with the Chagres river, as to the practicability of putting in dams and using part of the river below Matachin for slack-water navigation.

Discussion by NATHAN APPLETON.

Being a delegate to the recent Congress at Paris on this subject, I desire to express my conviction that that Congress honestly attempted to find the best route for a canal. The delegates soon came to the conclusion that the best canal would be one without locks and without a tunnel. The general question of location was referred to the technical commission of the Congress, and the conclusion of that commission, as reported to the Congress, was the basis of the final decision. The matter wasnot hastened. It was impossible for so large a Congress to remain in Paris and devote a long time to this subject. And at the beginning it was hoped by the delegates that the matter would require but a few days. But before a conclusion was reached a full fortnight had passed.

The technical commission, on the basis of all the surveys and examinations at their disposal, many of these being made by the Government of the United States, came to the determination that the only place where they could recommend that a canal should be constructed was on what is known as the Panama route.

To designate the Nicaragua route as the American plan in opposition to all others would be unfair. American engineers had examined the Isthmus and found between the oceans the same impassable mountain except at Panama, and therefore there they built the successful railroad now in operation.

To the suggestion that the decisions of the Paris Congress had been unfairly influenced by M. de Lesseps personally, the reply is, first, that the character of the members of that Congress was such as to make such a thing impossible; and secondly, that the character of M. de Lesseps is such as to make it impossible that he should attempt to use any improper influence. He is a man with a world-wide reputation, and

my personal acquaintance with him has made me know that his reputation is well deserved. He is the soul of honor.

If, when he has examined the route at Panama, he finds that a canal cannot be built, then he will be the first man to say so to all the world. If, on the other hand, he finds that the decision of the Paris Congress is correct, be will take hold of the project with vigor, such as he showed in the construction of the Suez Canal, and he will push it to completion and success.

Discussion by S. F. SHELBOURNE.

The plans presented for the Nicaragua Canal provide for locks of 400 feet in length. The requirements of commerce, even in the present, and certainly in the future, will not be satisfied with that length; there are already many vessels that would not be able to pass through them. If the present plans should be enlarged, then comes in the question of much greater cost, greater water usage, and more difficulty of operation and expense of maintenance.

For a distance of over seven miles, just back of Greytown, this canal would pass through a series of swamps and lagoons. In this section there is a perfect net-work of trunks and stumps of trees embedded in the alluvial drift from above, and as this portion of the canal would be excavated on the sea level, and, therefore, under water, the cost would be largely increased above the estimates. Besides, also, in this portion the width of bottom and slopes of the excavation are entirely inadequate for permanence, and the excavated material, if put upon the banks, would have to be removed a considerable distance away from the edge of the slopes, so as to avoid, on account of its softness, anything like an attempt at an embankment. In fact, for this portion of the canal, the estimated excavation is something less than one-half what it should be to afford a proper working channel.

On the eastern division of the proposed canal there are enumerated twenty-five streams or small rivers, which at certain seasons become rushing torrents. It will be difficult to provide for and manage these streams while the work of construction is in progress. To furnish a permanent way for these streams, 12 cesspools and 13 culverts are contemplated, at an estimate of only $340,400, while for 16 culverts on the Panama route the same parties have estimated the sum of $18,331,343. The disproportion of these estimates seems most remarkable.

In the slack-water river navigation proposed for this canal, many of the sharp curves are wholly impracticable for even moderate-sized vessels under a slow movement, but no provision has been made in the estimates for any improvement in this respect.

As to [the creation of a proposed harbor at Greytown by means of a jetty, it is clear that the same causes now operating would continue, and that an indefinite and continuous enlargement of the jetty would be requisite.

The prism of excavation for this canal at the bottom is altogether insufficient to allow two vessels of even moderate width and draught to pass each other without injury against the bottom of the slopes; so, too, the 7 miles of dredging at the entrance to Lake Nicaragua has been but meagerly and partially provided for, both as to width and depth.

But the heaviest items of deficiency are the estimates for the submarine and open rock cut excavations. There being nearly a million cubic yards of the former, and about 15 million cubic yards of the latter, to bring the estimates to a par with those for the San Blas route, there should be added to the cost for these two items alone $31,000,000.

When all these items of construction are taken into consideration, and the fact that an artificial harbor has also to be created at the Pacific end, it will be seen how entirely defective and delusive are the plans and estimates for this canal.

As to towage, it will be found requisite to tow sailing vessels for the whole 181 miles of the transit, and this expense for the Nicaragua route would be six times greater than for the same service on the San Blas route. So, too, the expense of operating the 21 locks of the Nicaragua route would be very great, and wholly extra, as compared with the San Blas route, involving a gang of men and costly machinery at each lock, so that, in fact, the cost of repair, operation and towage by the Nicaragua route would make a total sufficient to afford a handsome percentage of profit on the shorter and less expensive route by San Blas.

But the advocates of the Nicaragua scheme have assumed to reply that at least one tide-lock would be necessary both at San Blas and on the Panama route, and that, as ships pass locks in succession, one lock would afford as much obstruction and delay as twenty would. They have failed to consider that a tide-lock does not involve the same conditions as an ordinary lift-lock. Its gates may be sliding gates, with no necessity to be close fitting or water-tight, since the waters of the

Atlantic and Pacific can never be exhausted in balancing themselves alternately the one way and the other through such a lock ; and besides, while by Nicaragua one vessel only could pass at a time, a tide-lock on the Pacific end of the San Blas route could be so large as practically to amount to a basin, and pass through six to eight vessels at a time.

The objections which Mr. Menocal's paper urges against the San Blas route, relating to an assumed instability of the rock for the arch of the tunnel, I consider to be based on a misapprehension or a want of information as to the facts of the case, and his assumed illustrations are inapplicable and illogical. We know enough, indeed, about the character of the rock on this route to make it apparent that Mr. Menocal's fears on that score are largely imaginary.

Taking the Nicaragua route as a whole, with its conditions of length, its water-stairs of locks, with their liability to derangement, its want of natural harbors, its heavy items of maintenance and towage, it affords an exceedingly unpromising invitation to the shipping of the world. When, too, it is considered that the first cost of all this artificial construction, to be kept in order, would mount above a hundred million dollars, it may be foreseen that commerce would look long at the problem before finding a balance of advantage against its tolls and its dangers.

Discussion by Max E. Schmidt.

In Mr. Menocal's valuable paper occurs the following statement :

"It is evident the American Isthmus has been sufficiently explored to enable us to determine the difficulties that would have to be met in the construction of a ship-canal at the several places pointed out as representing favorable indications."

This statement cannot be justly sustained by the remarks in the paper itself. Of the three routes treated, Mr. Menocal says of Lieut. Wyse's plan :

"This line is not one of actual location, but was traced on a map of the Isthmus between Colon and Panama, constructed from such information as could be obtained from the maps of the railroad, and the survey of Mr. Garella, made in 1843, for a canal with locks, on a location other than that adopted by Lieut. Wyse. The elevations of the ground, given

in the profile, were also obtained, as near as practicable, from the same source of information, and the figures are, therefore, to say the least, a rough representation of the natural conditions."

Of the San Blas route, the author says likewise :

"This line has not been surveyed throughout its length."

Again, the knowledge of the geological formation of the Isthmus, obtained from surface examination mainly, is known to be so deficient that the author himself necessarily admits into the wide range of "guessing" some of the most important calculations introduced into the estimates of probable cost of the canal *à niveau*. The Nicarauga route, and the route from Colon to Panama, for a canal with locks, seem, therefore, to be the only ones that have been sufficiently surveyed to warrant correctness of the estimates. But does this fact exclude the possibility of the existence of other routes, which a thorough survey would develop, to be more practicable for inter-oceanic transit than either the Nicarauga route or the canal with locks between Colon and Panama ?

It would be folly, to be sure, to believe in the mysterious hints thrown out by the natives as to the existence of an open pass]; but, the question is, *has* the Isthmus been sufficiently explored to justify the recommendation of any one of the different routes, and if, as it appears not, would it not be more essential to discuss the urgency of an exhaustive survey of the entire divide. Mr. Menocal's statement that it is *evident* the American Isthmus has been sufficiently explored belongs, therefore, to say the least, to the category of open questions.

I would like to see a few longitudinal sections of the chain of mountains called the Cordilleras. Recognizing the great importance of securing the lowest pass, with such sections the location of the summit-level of the canal or tunnel could be judiciously determined. Certainly, American engineers would not hesitate to obtain the necessary information.

Excluding the Peninsula of Yucatan, there is located between the Atrato and the Isthmus of Tehuantepec, a territory having a surface area of about 215 000 square miles. This territory is narrowly spread over a distance of nearly 1 600 miles in length, and constitutes what is called the American Isthmus. In this distance perhaps eight lines have been run from ocean to ocean, and a few additional ones from tide-level up, or partly up the divide. How much of the adjacent country has been seen by the parties who surveyed these lines ? Would it be wise to undertake the expenditure of such a vast amount of money, when per-

haps in later years posterity would discover a place where this same canal might have been built cheaper, better and shorter.

As to the details of the three projects treated in the paper, it would be interesting to hear something positive about the methods which are to be employed on the tunnels of the "*canaux à niveau.*" How is the large laboring force which will be required to be distributed to finish the work within any reasonable time? Are pits to be sunk in the line of the canal, and how are they to be drained?

It may be inferred from the large mean annual rain-fall, that numerous springs will be met with in the excavation of the tunnel. Mr. Menocal has laid bare the kernel of the problem by exposing the difficulties that will be encountered from the works becoming flooded.

It has been stated that many vessels afloat exceeded the dimensions of the locks proposed for the Nicarauga route. This is an important statement. If the vessels of the present day cannot be accommodated in the locks on this route where is the revenue to come from fifty years hence? The locks ought to be large enough to suit the ships of the future, for otherwise the canal which is now built to facilitate commerce will place a restriction upon the increase of tonnage which must be expected in the future. In this connection it would be interesting to know whether the summit water supply on the Nicarauga route can be so regulated as to be sufficient for lockages of 500 feet in length and 75 feet in width. This enlargement would require an addition of nearly 200 000 cubic feet of water for each lockage. If additional feeders have to be provided for, from what source can they be taken, and what will be their expense of construction? Again, the maintenance of the dredged channel in the lake may become an item of expense, and, under the proposition of a bottom width of only 80 feet for the 26-feet channel, the speed of the vessels, set down at ten miles per hour for lake navigation, seems too great to be safe. The length and duration of transit are of secondary importance, however. Whether 30, 45 or 181 miles long, and whether 6, 10 or 38 hours in transit, what do these figures amount to when compared with the time and distance required to circumnavigate the South American Continent? Safe and commodious harbors, safety in transit, and some guarantee for the safety of the capital by a permanent usefulness of the work, will insure the construction of this highway, sooner or later.

Discussion by THOMAS J. LONG.

For the purpose of obtaining more definite information concerning the size of vessels that may have to be accommodated by an inter-oceanic canal I have carefully compiled, from the Liverpool Registry of Steam Merchant Vessels for 1879–'80, tables which I think will be of value in any discussion of the canal question. The registry above referred to is the most complete and reliable record of the kind. The Great Eastern is not included in the table given below, on account of its exceptional size:

TABLE NO. I.

REGISTERED LENGTHS OF VESSELS.	Number of Vessels.	Total Number.
Between 480 feet and 490 feet	1	1
" 470 " 480 "	0	1
" 460 " 470 "	1	2
" 450 " 460 "	3	5
" 440 " 450 "	3	8
" 430 " 440 "	6	14
" 420 " 430 "	10	24
" 410 " 420 "	7	31
" 400 " 410 "	20	51
" 390 " 400 "	18	69
" 380 " 390 "	32	101
" 375 " 380 "	23	124
" 370 " 375 "	9	133
" 360 " 370 "	48	181
" 350 " 360 "	68	249

NOTE.—The American Lloyds for 1878 gives a length of 400 feet or more to three vessels which are given less than 400 feet in the above table.

TABLE NO. II.

Registered Tonnage.	No. of Vessels.	Estimated Tonnage.	Total No. of Vessels.	Total Estimated Tonnage.
Between 5 000 and 6 000	7	38 500	7	38 500
" 4 000 " 5 000	40	180 000	47	218 500
" 3 000 " 4 000	164	574 000	211	792 500
" 2 500 " 3 000	143	393 250	354	1 185 750
" 2 000 " 2 500	279	627 750	633	1 813 500
" 1 500 " 2 000	614	1 074 500	1 247	2 888 000
" 1 200 " 1 500	543	733 050	1 790	3 621 050
" 1 000 " 1 200	471	518 100	2 261	4 139 150

TABLE NO. III.

"MERCHANT VESSELS OF THE WORLD."

(From "Bureau Veritas," quoted in Van Nostrand's Mag., Dec., '79.

No. of Steamers	5 897	Tonnage	6 173 935 = 30 per cent.
" Sailing Vessels	49 024	"	14 109 605 = 70 "
Total	54 921	"	20 283 540 = 100 "

Many of the vessels included in the above tables are engaged in the transatlantic trade; but there is a large number remaining which are engaged in the general carrying trade, many of which would, probably, take advantage of a canal across the Isthmus, if of sufficient size to accommodate them.

In Table I. there are 54 steamers (including those mentioned in the foot-note to the table) which are 400 feet or more in length, and could not, therefore, be passed through the locks of the Nicaragua Canal, if these were built of the dimensions given in the paper. Two of these are engaged in the trade between the United States and Japan and China, in the fleet of the Pacific Mail Company—namely, the City of Peking, 420 feet long, and the City of Tokio, 402 feet long.

But the registered length does not show the length of vessel which would be debarred from using a 400-foot lock, for we must remember that the registered length is measured on the water line, whereas the

length of vessel which can be accommodated in a lock must be measured on a line at a distance above the water line equal to the height of the top of the gate above the water in the lock when it is at its lowest level; a distance, in this case, equal to $5' + 10'.3 = 15'.3$. The length of a vessel measured on this line is always greater than the registered length, and the ratio of the difference to the registered length increases as the size of the vessel decreases. Thus, in the case of the City of Berlin, the longest vessel in the above table, the registered length is 488.6 feet, but the length measured as above is 500 feet. Measurements of vessels with prows of greater curvature would show a still greater difference. It is doubtful if many vessels of a greater registered length than 375 feet could be passed through a 400-feet lock, and for this reason 124 vessels in the above table would be excluded from the canal.

It is the opinion of those engaged in the carrying trade that merchandise can be carried more economically in large vessels than in small ones, and that the limit in size has not yet been attained. During the past year the Orient, 460 feet long, the Arizona, 452 feet long, and the Gallia, 430 feet long, have been launched; and during the coming year the Cunard Company will send out a steamer 500 feet long, 50 feet beam and 7 500 tons measurement ; and the Inman Company will follow with one 525 feet long and 53 feet beam. Other steamship companies say that they intend to increase their fleets by larger vessels. All of which tends to show that the Inter-Oceanic Canal Commission were mistaken when, in their report to the President in 1876, they stated, as a reason for keeping the length of lock in the Nicaragua route at 400 feet, that "the "canal should be built for the class of vessels best adapted to extended "navigation, which class would in general follow the routes of prevail-"ing winds. *Extreme length should be discouraged, as well as for a true "economy as for safety of passengers.*"

If the canal is to be one with locks, a length of 400 feet will certainly be inadequate; and the present demands of commerce, or, at least, those of the near future, require a length of at least 600 feet. This change would increase the cost of the locks by about fifty per cent.

Another point to be taken into consideration is the draught of the large steamers. Very many of those which have a length of 375 feet or more draw about 26 feet of water, and it is not uncommon for some of the larger ones to leave this port drawing nearly 27 feet. In view of this it is evident that a depth of 26 feet in a canal or lock will be

another hindrance to vessels passing through. If Rankine's rule be adopted the depth of the canal will be 1½ feet deeper than the greatest draught of vessels, which will give a depth of water of at least 28 feet.

A breadth of beam of 44 feet or upward is not at all uncommon in large steamers, and, as stated above, some of the steamers of the future will have a beam of more than 50 feet. Evidently, a greater width of canal is required than that given by Mr. Menocal.

It would seem, then, in view of the fact that in the carrying trade steam is taking the place of sails, and large vessels the place of small ones, that a canal which is to accommodate the trade of the near future, and which is to be built for the ships, and not the ships for it, will require a depth of at least 28 feet; and if there are to be locks they must not be less than 600 feet long.

From Tables II. and III. it will be seen that about twenty per cent. of the tonnage measurement of all the vessels in the world—both steam and sailing—is in vessels of over 1 000 tons measurement, and that it comprises about sixty-seven per cent. of the total tonnage measurement of the steamers. The question whether vessels of 1 000 tons and upward can be locked in twenty minutes, as estimated in Mr. Menocal's paper, becomes one of very great importance, and the figures given in the table will be of use to every engineer who may study the subject.

Discussion by EDWARD P. NORTH.

It may seem premature, with the data in hand, to estimate on the total cost of an Inter-oceanic Canal; but this total cost is such an important factor in the practicability of any canal scheme, that it should not be neglected.

It is well known that in addition to the engineers' or absolute cost of any work, there are other expenses—some perfectly legitimate—which depend so largely on the honesty and discretion of the board of direction on the one hand, and on the confidence of the public in the scheme on the other, that it is almost impossible to correctly estimate them.

An analysis of the cost of the Suez shows that the two items were in round numbers—

Absolute cost	$48 000 000
Expenses of administration	50 000 000
Total	$98 000 000

As in the present case there are rival projects in the field, and no route is now known that does not present complications, which, though doubtless surmountable, will tend to alarm timid investors, and as the work is much further from the accumulated capital and low rate of interest of Europe, it may be assumed that even under Count de Lesseps' experienced guidance, these administrative expenses will amount to at least 115 per cent. in place of the 104 per cent. of the Suez Canal.

As a careful location has been made only on one route, and that is now generally admitted to require revision in the matter of curves, locks, &c., no estimate of the absolute cost can be advanced as more than a rough approximation, but the general impression seems to be that it will be in the neighborhood of $120 000 000; if to this $138 000 000 (115 per cent.) be added for administrative expenses, we will have the cost at completion $258 000 000.

It can hardly be expected that on the completion of this canal the routes of commerce will immediately change, and even if that were probable, the investors must wait for an increase born of the facilities afforded by the canal before they can hope to receive a satisfactory income from their expenditure.

As even a small railroad enterprise, shortly after completion, passes through the various phases of floating debts and ingeniously-named mortgages—if happily it escapes the hands of receivers, this canal, if ever built, must probably see its immense capital nearly if not quite doubled before its dividends can equal 15½ millions or 6 per cent. on the cost at completion.